

THE EFFECTS OF AIRCRAFT OVERFLIGHTS ON VISITORS TO U.S. NATIONAL PARKS

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1. INTRODUCTION

Aircraft overflights of public lands, and specifically of US National Parks, increasingly have become a source of sound intrusions into otherwise undisturbed natural environments. In response to both park management and public concern about the effects of these overflights, several studies have been conducted to examine the benefits and the impacts of aircraft flights over National Parks. This paper summarizes the methods and results of two such studies: 1) Dose-Response studies conducted at six sites in Grand Canyon, Hawaii Volcanoes, and Haleakala National Parks; 2) a Cognitive Survey conducted at a site in White Sands National Monument. In addition, this paper offers an approach for using the results of the Dose-Response studies to judge the relative impacts of aircraft overflights on visitors.

It is important to emphasize that the subject addressed here is the effect of aircraft overflight noise on park visitor experience, as judged by the visitors themselves. But this self-defined experience is only one of several dimensions of concern to US National Park management. It is not unusual for visitors to be unaware of the type of experience provided by the park or by a specific park setting. Park management objectives, such as resource protection, are also significant in determining the appropriateness of aircraft overflights. These management objectives can be fundamental to the National Park Service in general, or may reflect Congressional mandates for a specific park. Therefore, it is important to keep in mind that visitor reactions are not likely to be the sole or final determinant of whether or not aircraft overflights are acceptable for a given park setting.

The following section, Section 2, provides general descriptions of the two types of studies reported here. Next, Section 3 describes the methods and results of the dose-response

studies, while Section 4 describes the details for the Cognitive Survey. Section 5 presents a method for using the results of the Dose-Response studies to characterize the relative impacts of overflights using only acoustic data. Finally, Section 6 summarizes the author's observations about the overall value of the information provided here.

2. BACKGROUND

The two types of studies reported here have quite different objectives. The Dose-Response studies statistically relate visitor judgements of aircraft overflights (response) to a quantitative measure of the sounds the visitor could have heard (dose). The Cognitive Survey is neither statistical nor quantitative. Rather it is a means for learning about the thought processes a visitor uses in answering specific survey questions about the effects of aircraft overflights.

The Dose-Response studies were conducted at specific park sites by simultaneously measuring sound levels, identifying sources of the sounds measured, and surveying visitors who were present at the site during the measurements. Thus, for each visitor surveyed, a complete quantitative, time-stamped record of sound levels and sound sources was created to associate with that visitor's time at the site. By statistically analyzing several hundred such records of visitor responses and sound exposures, mathematical relationships between the two are developed.

The Cognitive Survey also depends upon surveying visitors at a site, but focuses on obtaining visitors' interpretation of the questions asked. For the Cognitive survey, the dose-response study questionnaire was used, but after specific questions of interest, "probe" questions were asked. For example, one of the primary questions asked the visitor whether he/she was bothered or annoyed by aircraft noise. (Possible answers being: not at all, slightly, moderately, very, extremely.) After this question was answered, the visitor was asked probe questions about what the word "annoyed" meant, and what conditions would be necessary to cause him/her to have increased annoyance. The Cognitive Survey provides several useful explanations of how park visitors judge the sound of aircraft.

3. DOSE-RESPONSE STUDIES

3.1 The Studies

Four sites in the Grand Canyon and one each in Hawaii Volcanoes and Haleakala National Parks were selected as data collection sites.¹ The working hypothesis used in the design of the data collection and analysis was that visitor reaction, as measured with appropriate survey questions, could be correlated with the aircraft overflight sounds that the visitors could have heard while visiting the site. At the site, simultaneous sound level measurements, visitor surveys and sound source identification provided three data bases that were then combined. The combined data base permits association of each visitor's response with various metrics of the sound levels measured during the visitor's time on-

site. Statistical analyses (logistic regression) yielded dose-response curves that show what percent of the visitors were adversely affected at various levels of aircraft noise.

3.2 Site Selection

Because of the effort and expense required to collect data, measurement sites were carefully selected to yield a large number of completed surveys for visitors who were present during aircraft overflights. The requirement for accurate acoustic data also placed conditions on the site selection. The following factors were considered when identifying the sites for data collection.

Visitation Rate – Enough visitors were needed to collect more than about 100 useful surveys in four days of effort. Locations were identified that were likely to experience between 5 and 10 groups of visitors per hour.

Number of Overflights - Locations were identified that would have at least 2 to 4 overflights per hour to maximize the likelihood that most visitors would be present during an overflight.

Size of Area – The size of the area used by visitors was kept small when possible so that sound levels for the entire area could be characterized by use of a single sound monitor. (At the sites in Hawaii, however, more than one monitor was required, and algorithms had to be developed for associating a specific sound monitor with each visitor as a function of time, depending upon estimates of the visitor's location while at the site – a complex process.)

Ease of Interviewing – In order to easily observe and time of the visitors' entry into the site, and to easily intercept the visitors before they left the site, park locations with a single entry / exit point were chosen.

Visit Duration – Most visitors were at the sites long enough to have a high probability of experiencing at least one overflight. Sites where visitors usually stayed for at least 15 minutes were preferred.

Few Additional Noise Sources – Because the effort was designed to measure and assess the effects of aircraft, sites selected were largely unaffected by non-aircraft sources of noise.

All Visitor Activity Outdoors – Finally, the sites could have no buildings or structures that visitors might enter and that would affect the degree of sound exposure they experienced.

Table 1 summarizes the types and amount of data collected at each of the six sites. In the analysis, data from Havasu Creek were not used because background sound levels (produced by waterfalls) were loud enough to prevent visitors from hearing aircraft and to prevent accurate measurement of the aircraft.

Park	Study Area	Type Area	Number of Respondents	Range of Typical Background Leq, dB(A)	Aircraft per Hour (approx.)
Grand Canyon	Lipan Point	Overlook	193	40-50	24
	Point Imperial	Overlook	124	25-40	22
	Havasus Creek	Short Hike	30	65-70	9
	Hermit Basin	Short Hike	32	20-25	31
Haleakala	Sliding Sands	Short Hike	213	20-30	8
Hawaii Volcanos	Wahaula	Short Hike	180	35-45	9

Table 1. Dose-Response Sites

3.3 Data Collection

Interviews - Figure 1 shows a typical site configuration for the data collection effort. Interviewers were located in a position to easily see visitors arriving at and departing from the site. The site in this case, Point Imperial, was an observation platform where visitors could stand and view the Canyon. As a visitor entered the site, the time of arrival was noted. When the visitor left the site, an interviewer would intercept the visitor and ask if a brief interview could be given. The interviewer would note the time of intercept so that the visitor's complete time at the site could be determined.

The interviewer used a survey instrument that was designed to explore visitor judgements of the effects of aircraft noise. The instrument was pre-tested to insure that questions were unambiguous and that administering it took no longer than 5 to 7 minutes. Questions asked whether the visitor heard aircraft, whether aircraft noise caused annoyance or interfered with enjoyment or their appreciation of natural quiet and the sounds of nature.

Sound Monitoring - The sound monitor was located near by, as unobtrusively as possible, in a position where it would receive virtually the same sound levels as those experienced by visitors at the site. This monitor measured and stored a complete time history of one-second A-weighted sound levels. Tape recordings were also made periodically during data collection to document the frequency content of the sounds.

Sound Source Identification - An observer was located near the monitor. This observer created a detailed, second-by-second log of all sounds heard. He / she used a palm top computer to record the start time of each change in acoustic environment according to a pre-arranged hierarchy of sound sources. Thus, a second-by-second record of the audible sound sources was created for later association with the A-weighted time history. This set of data - the second-by-second record of sound sources, the interview results, and the A-weighted time history - represented all the necessary data for computation of a multitude of sound exposure metrics to associate with each visitor's responses.

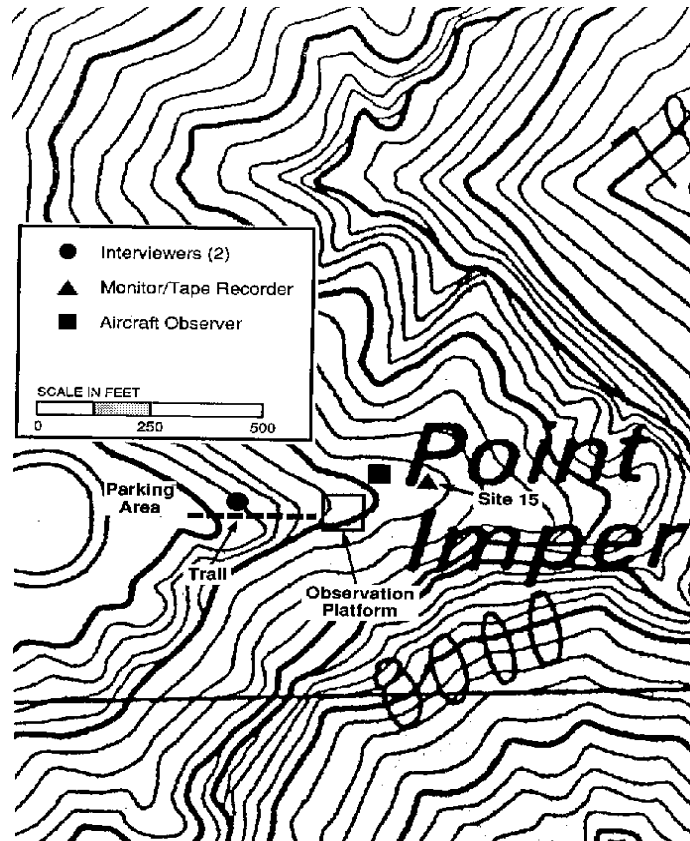


Figure 1. Site Configuration for Dose-Response Data Collection

3.4 Data Analysis

The three collected data sets (visitor survey, sound level data, and source identification) were combined, and sound metrics computed for each visitor's time at the site. Specific doses were computed for each visitor, and these doses and the visitor responses were analyzed using logistic regression to develop the dose-response relationships. First, two doses and two responses were chosen for analysis. Then, the responses were "dichotomized" (divided into two categories) and logistic regression used to develop the relationships.

3.4.1 Doses

The two sound metrics (or doses) that proved to be well correlated with visitor responses are:

- 1) The percent of time aircraft were audible while the visitor was at the site.

This dose was determined by using the observer logs to calculate the percentage of the total visitor's time on-site that aircraft could be heard. The calculation is simply a ratio of the number of seconds the observer logged aircraft as audible to the total number of seconds that the visitor was at the site.

- 2) The difference between the aircraft produced equivalent sound level, $L_{eq}(\text{aircraft})$, and non-aircraft produced or background equivalent sound level, $L_{eq}(\text{background})$ [or $L_{eq}(\text{aircraft}) - L_{eq}(\text{background})$] during the visitor's time at the site.

Equivalent sound levels must apply to a specific period of time. $L_{eq}(\text{aircraft})$ was computed for the time the visitor was at the site. It is the total sound energy produced by aircraft that were heard while the visitor was at the site, adjusted to the total time the visitor was at the site. Hence, for a given amount of aircraft sound energy (e.g., for a given number of aircraft overflights), the longer the visitor was at the site, the lower would be the $L_{eq}(\text{aircraft})$ for that visitor.

$L_{eq}(\text{background})$ was computed using the sound levels that were measured when no aircraft were audible. The $L_{eq}(\text{background})$ measured during these times was treated as representative of the background for the entire time that the visitor was at the site.

3.4.2 Responses

Two visitor responses were analyzed with respect to the two doses. Specifically, responses to the two following questions were used:

- 1) Were you bothered or annoyed by aircraft noise during your visit to [name of site]?

Possible responses to this question were "not at all," "slightly," "moderately," "very," and "extremely."

- 2) Did the sound from aircraft interfere with your appreciation of the natural quiet and sounds of nature at the site?

Possible responses to this question were also "not at all," "slightly," "moderately," "very," and "extremely."

3.4.3 Logistic Regression

Logistic regression is a statistical analysis process that yields the probability of an outcome for a given value of the independent variable. In this analysis, logistic regression is used to determine the likely visitor response for given sound doses. For example, each visitor's response and the dose received by each visitor are used to compute relationships that give the percent of visitors who said they were annoyed for various degrees of sound exposure.

To conduct this logistic regression, visitor responses to the two questions were first dichotomized by categorizing answers of "not at all" or "slightly" as "no" responses, and answers of "moderately," "very," or "extremely," as "yes" responses. Logistic regression then computes the percent of visitors who answered "yes" (that is, for example, reported they were moderately, very or extremely annoyed) for various values of the sound metrics.

3.5 Results

The resultant relationships are presented in Figures 2 through 5. Figures 2 and 3 give the relationships for the metric of difference in L_{eq} (aircraft L_{eq} minus background L_{eq}) for the two responses, while Figures 4 and 5 show the results for the metric of percent of time aircraft are audible. Three observations are of some significance. First, the sites of Hermit Basin, Haleakala and Wahaula are always more sensitive than the two sites of Point Imperial and Lipan Point. That is, visitors at these three sites report more annoyance or interference with natural quiet than do visitors at the other sites, for a given level of sound exposure. Though the reasons for this higher sensitivity are speculative, it is known that at these three sites visitors walked some distance from their cars; these three sites may be considered "short-hike" sites where visitors committed some time to walking along a trail. Both Point Imperial and Lipan Point are Canyon overlook opportunities where visitors walked only a short distance to the overlook. Hence, it may be that visitors who commit some time to a particular park experience are likely to be more sensitive to the intrusions of tour aircraft noise than are visitors at more easily accessible sites.

A second important observation is that for a given level of sound exposure, more visitors report interference with natural quiet than report annoyance. This difference, reflected also in other surveys of park visitors², can be useful for park management purposes. For sites where the experience of natural quiet is a primary management objective, aircraft noise must be more limited if a given percent of the visitors are to be protected. Dose-response results of the form of Figures 3 and 5 can provide guidance about how to set these limits to minimize visitor judgements of interference with natural quiet. For example, to limit the percent of visitors reporting interference with natural quiet to less than about 25% at the "short-hike" sites, audible intrusions of aircraft noise should be limited to less than about 5% of the time. For sites where natural quiet is not or cannot be expected, information of the type in Figures 2 and 4 can be used to limit visitor annoyance to a small percentage of the visitors. (Section **Error! Reference source not found.** provides additional interpretation of this difference between visitor judgements of annoyance and of interference with natural quiet.)

A final observation regarding these results is that the relationship of the sites to each other, in terms of sensitivity (vertical position of the curve on the plots), varies depending not only upon the response (annoyance or interference), but also upon the dose metric. Though this variation is surely due in part to limited sample sizes, it is probably also due to the fact that the two dose metrics are very weakly correlated (correlation coefficient of 0.26).³ This lack of correlation is shown graphically in Figure 6 which plots percent of time audible *versus* sound level difference for all visitors interviewed. Lack of correlation means that the two doses provide different information about the sound exposure so that it is informative to know the values of *both* metrics for a site. Section 5 below suggests a method for using both metrics to evaluate sound intrusions at park locations.

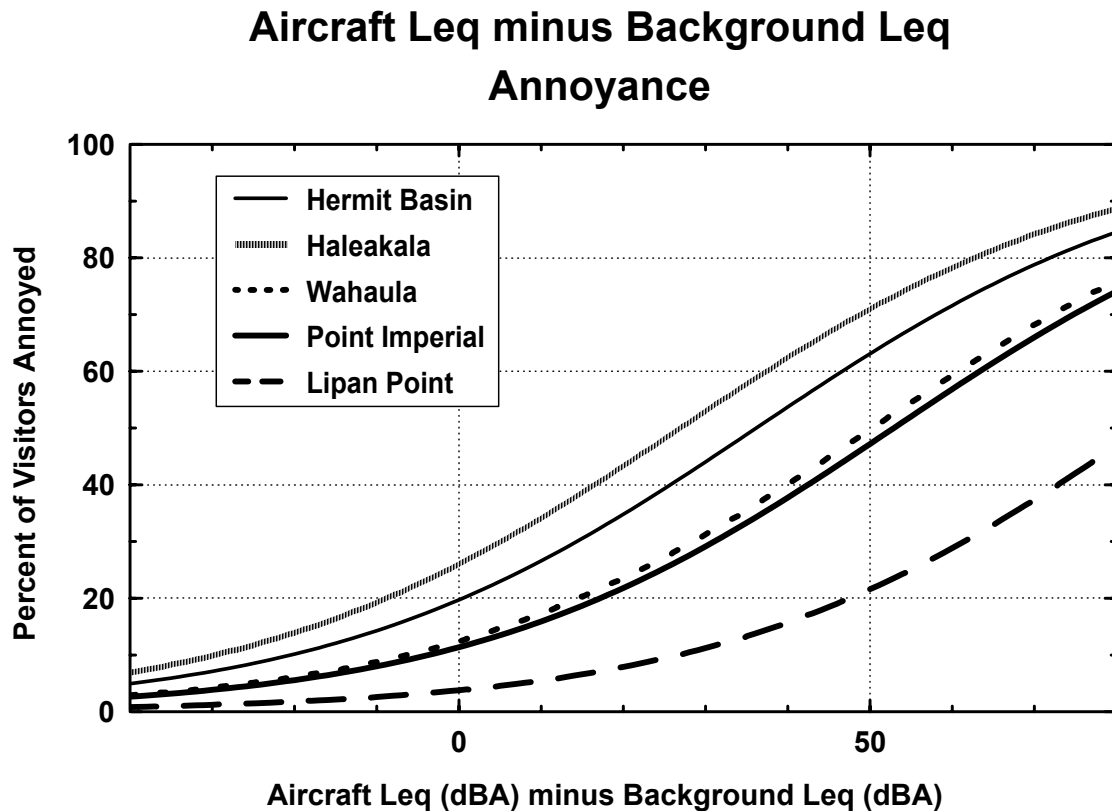


Figure 2. Dose-Response Relationship, Annoyance v. Difference in Leq

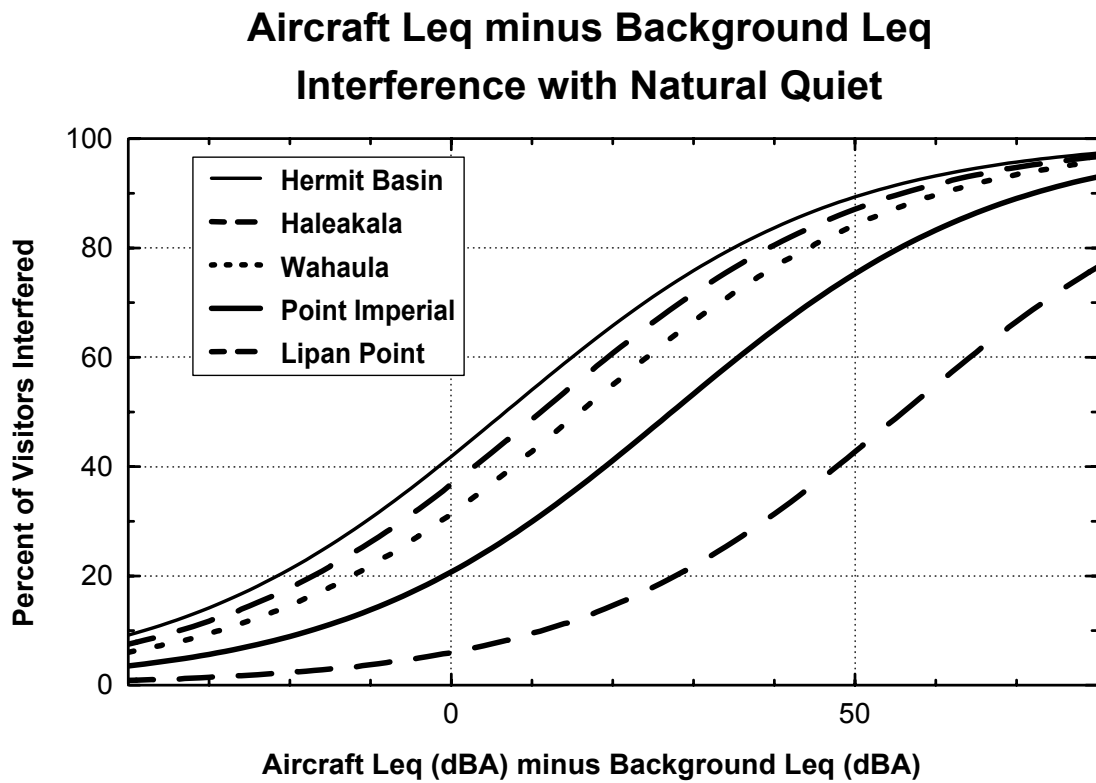


Figure 3. Dose-Response Relationship, Interference v. Difference in Leq

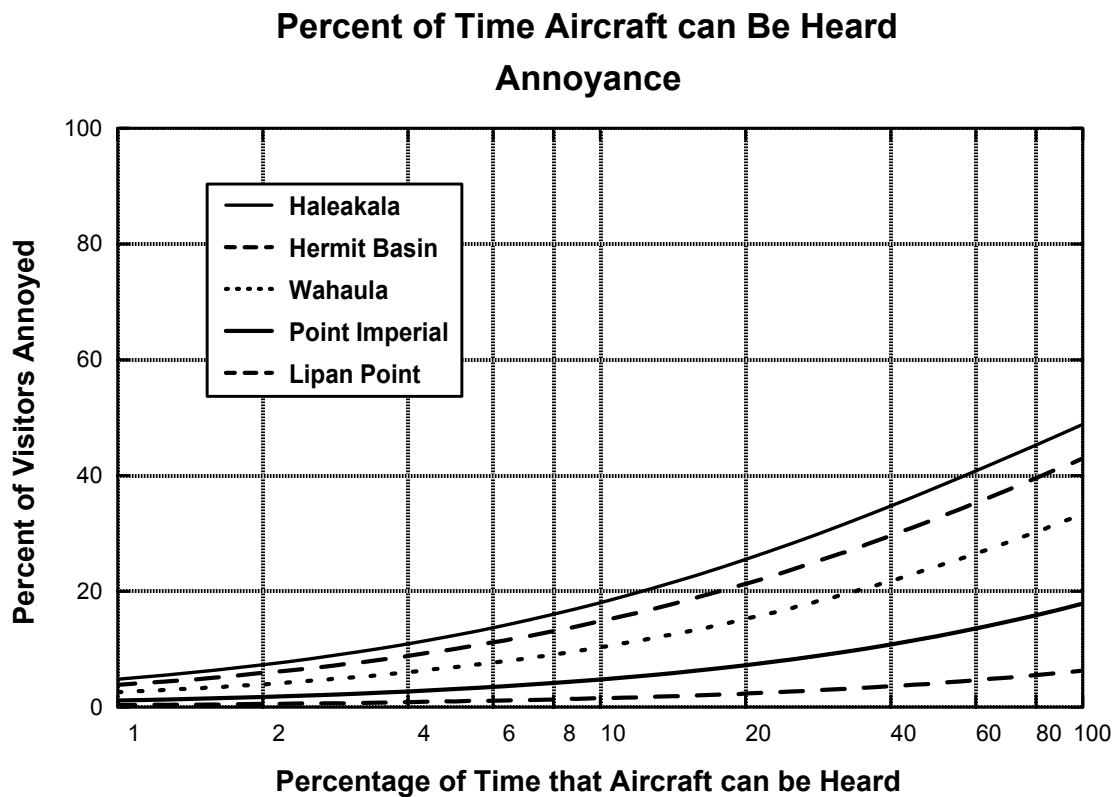


Figure 4. Dose-Response Relationship, Annoyance v. Percent of Time Audible

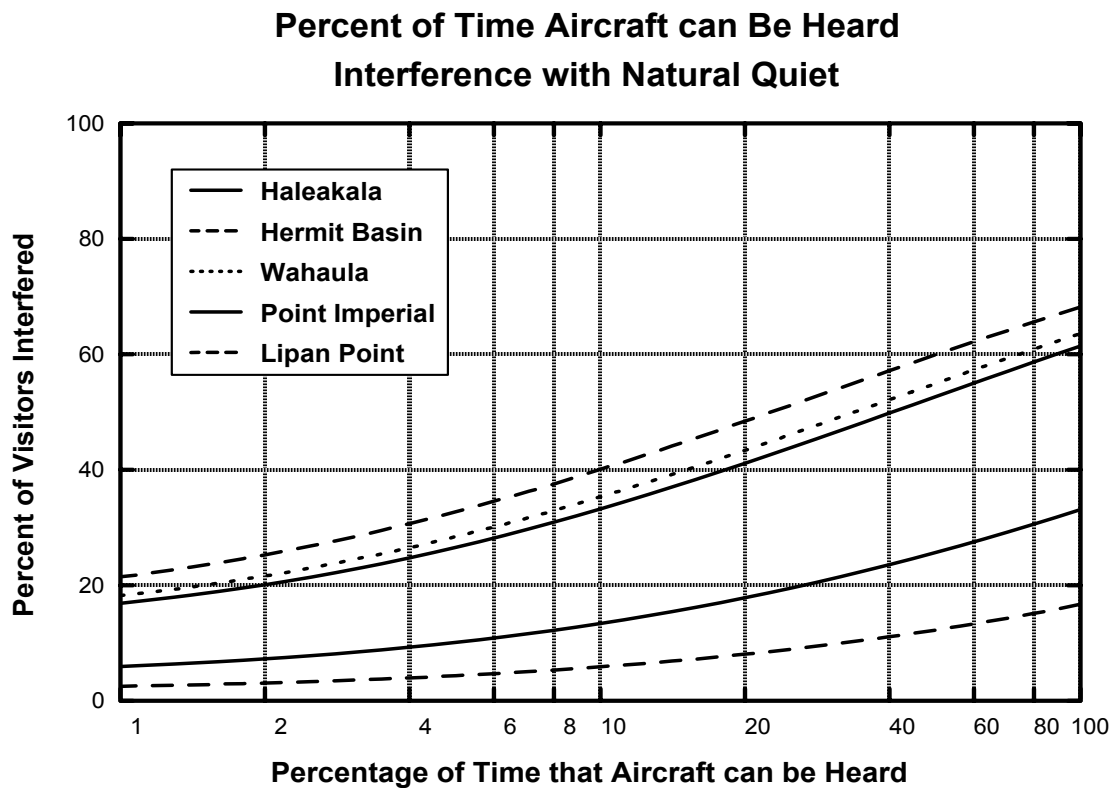


Figure 5. Dose-Response Relationship, Interference v. Percent of Time Audible

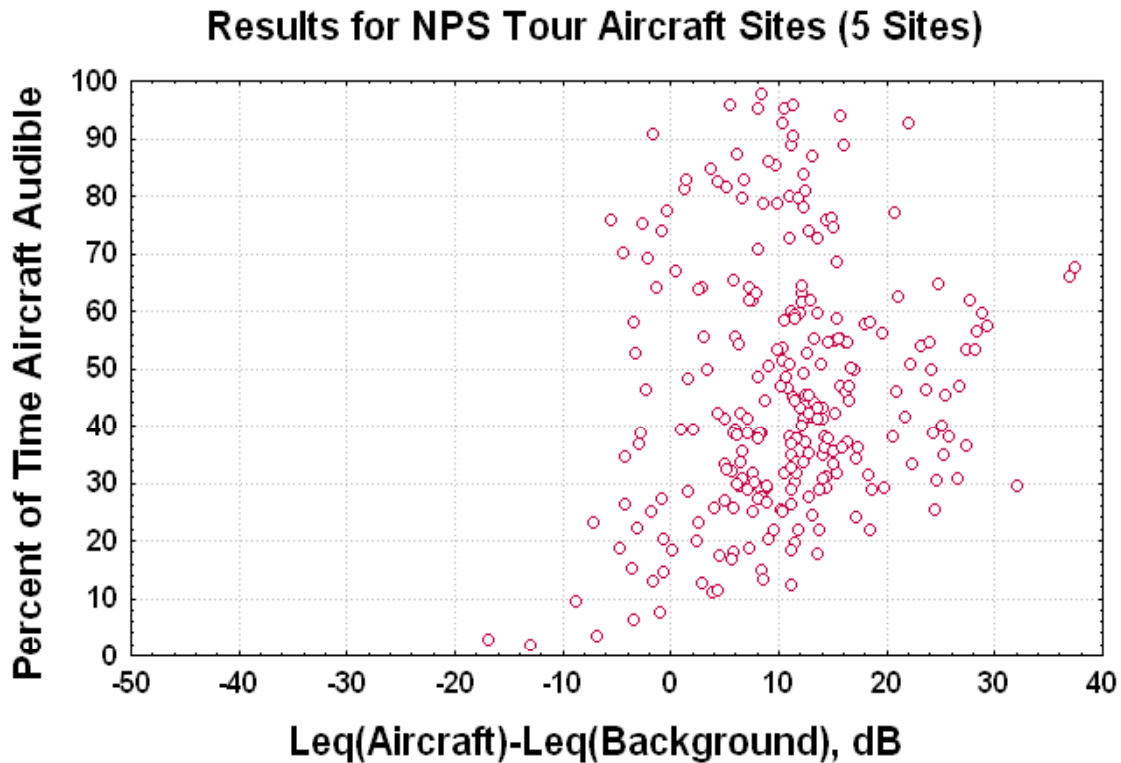


Figure 6. Demonstration of Lack of Correlation between Time Audible and Leq Difference

4. COGNITIVE SURVEY

The consistent differences between visitor judgements of annoyance and interference led to questions about respondents' interpretation of the questions. In an effort to better understand visitor responses, cognitive interviews were designed and conducted at White Sands National Monument in conjunction with a US Air Force sponsored dose-response study.⁴

4.1 Method

Cognitive interviewing is simply asking the respondent additional “probe” questions about their interpretation of specific words or phrases used in the basic questionnaire, and exploring how they arrived at the answers they gave. In this case, the standard survey instrument was used in the actual park setting, except that after obtaining responses to several specific questions of interest, particularly the annoyance and interference questions, additional questions were used to elicit visitor interpretations of specific concepts.

4.2 Results

The cognitive surveys, conducted of 21 individuals during a three-day period provided the following five conclusions.

1. Aircraft noise appears to be a factor that visitors may not consider when asked to evaluate their park experience in an open-ended question format. As a result, open-ended questions, such as “What did you like the least about your visit to [park]?” are probably not good indicators of the seriousness of problems from aircraft overflight noise at parks.
2. Visitors have a clear and widely shared understanding of the concept of “natural quiet and sounds of nature.” Natural quiet is viewed as the absence of any human-made sounds, allowing them to hear nature as it is.
3. Most visitors make a distinction between the terms “interference” and “annoyance.” Interference is perceived as an objective term, describing something that prevents them from doing what they want to do; it is an interruption or a distraction. Annoyance is perceived as having an emotional, evaluative component. For example, many respondents associate a negative reaction “makes me mad,” “causes my blood pressure to rise” with the term annoyance.
4. Aircraft noise interference can result in annoyance but does not necessarily do so. The aircraft noise probably must exceed a certain level or number threshold before it is perceived as annoying.
5. Respondents indicate that interference can be a short-term occurrence, such that once the noise source has passed the perceived interference ends. Annoyance, however,

because of the emotional component is more long lasting. It seems reasonable to consider annoyance as the reaction that causes a visitor to evaluate the experience as negative or to consider registering a complaint.

5. JUDGING RELATIVE INTRUSIVENESS

This section proposes a quantitative method that can be used to assist in making judgements about sound intrusions at park sites. The method quantitatively describes a site by using in combination the two sound metrics that have been shown to correlate well with visitor judgements of aircraft sound intrusions – percent of time audible and difference in L_{eq} . Dose-response results are used to help judge these quantitative descriptions. The two metrics quantify the degree and level of the sound intrusions, and the dose-response results tell what values of these metrics cause “too many” visitors to register annoyance or interference.⁵

As a first step in developing the method, thresholds of acceptability in terms of both metrics are identified. Figure 7 presents again the dose-response relationship for annoyance as a function of difference in L_{eq} , and Figure 8 shows the annoyance results for percent of time audible. As an example, these figures are used to identify limits on intrusions such that no more than 25% of visitors to a typical or average “short hike” sites would report annoyance. These figures show that this goal can be met if difference in L_{eq} is no greater than 5 dB, and if percent of time audible is no greater than about 30%. Figure 9 identifies this range on a graph. In other words, sites for which measurements (or computations) show that percent of time audible is less than 30% of the time, and the difference in L_{eq} is less than 5 dB should provide a park sound environment which produces annoyance reactions in less than 25% of visitors. Such sites would plot within the shaded area of Figure 9.

By similarly finding thresholds that limit *interference with natural quiet* to 25% of visitors at short hike sites, and that limit annoyance to 25% of visitors at *overlook sites*, two other areas may be identified. All three areas are identified in Figure 10, along with measurement results from eight sites in Rocky Mountain National Park. (Results at only seven of these sites are shown in Figure 10.) The small white area in the lower left limits interference with natural quiet to 25% of visitors; the largest shaded area limits annoyance to 25% of visitors at overlooks (visitors at the overlook sites of Point Imperial and Lipan Point proved to be quite insensitive to aircraft noise). The plotted points are numbered by site, and letters distinguish one measurement period from another.

Though the presentation of site information provided by Figure 10 is certainly not complete, this approach offers one means for quantitatively comparing different sites and different times at a given site. If many measurements are made at a site, for example, the distribution of measured results will suggest the significance of the noise intrusions and indicate whether changes are warranted to meet goals for visitor experiences.

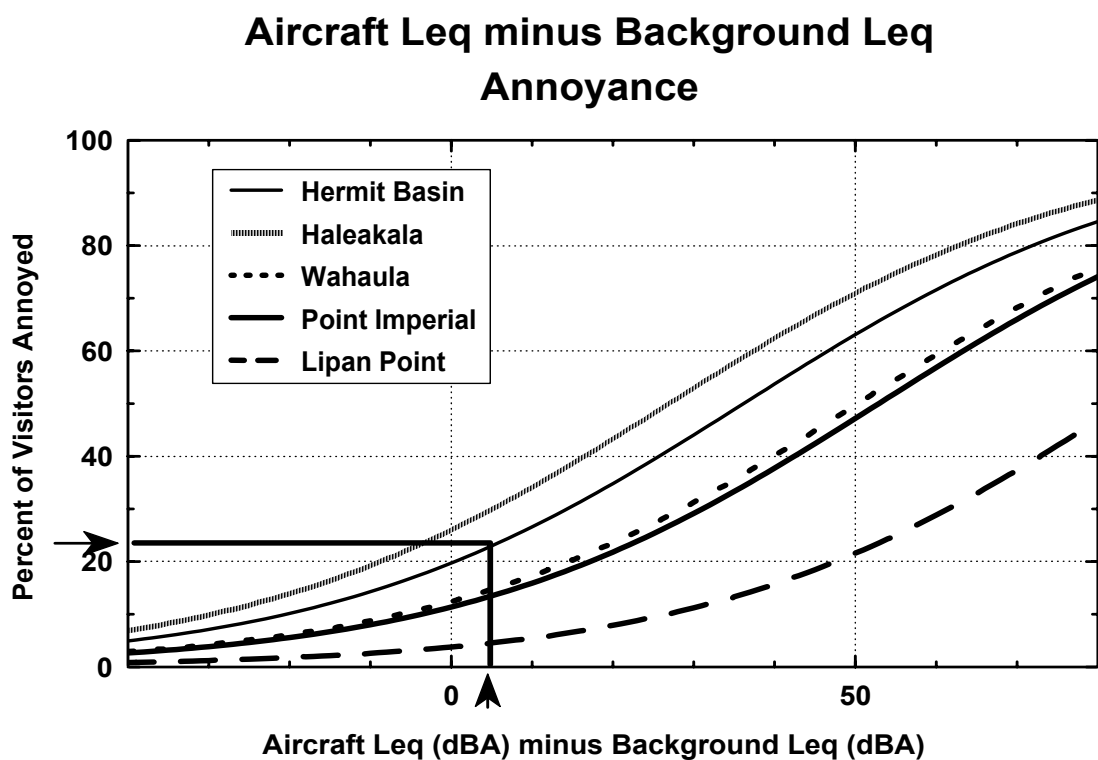


Figure 7. Determining Difference in Leq that Produces Annoyance in 25% of Visitors

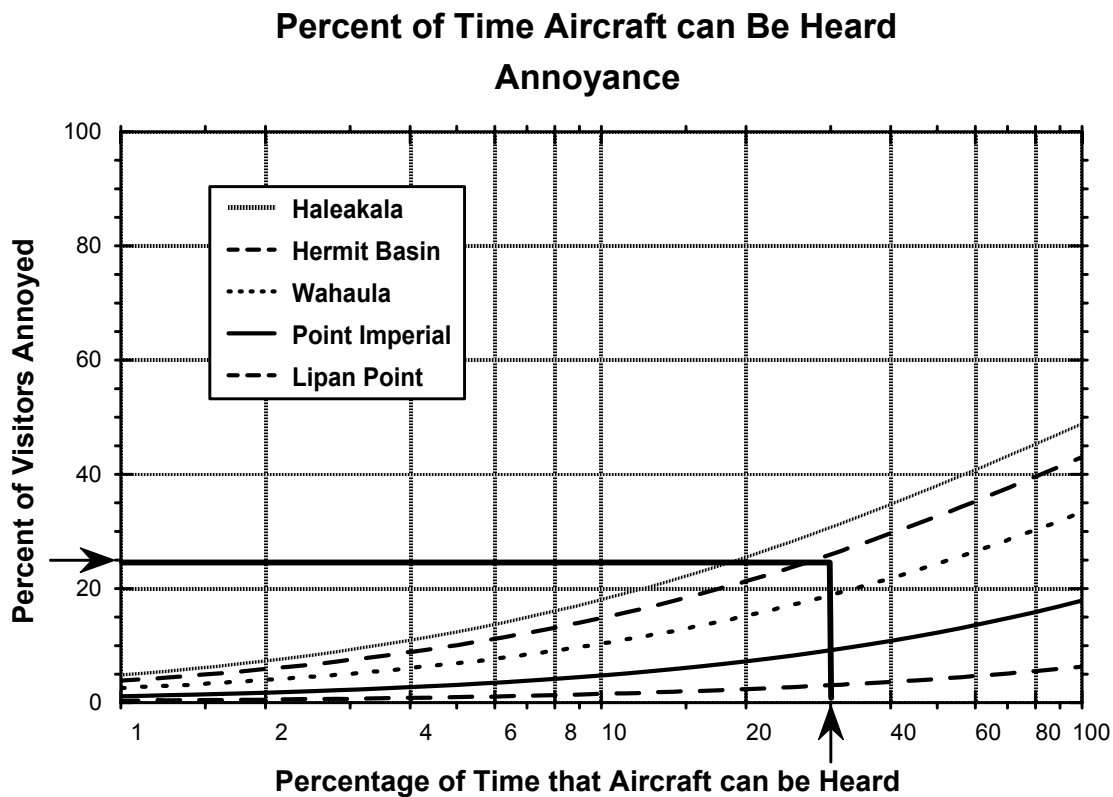


Figure 8. Determining Percent of Time Audible that Produces Annoyance in 25% of Visitors

Values that Limit Annoyance to 25%

Short Hike Sites

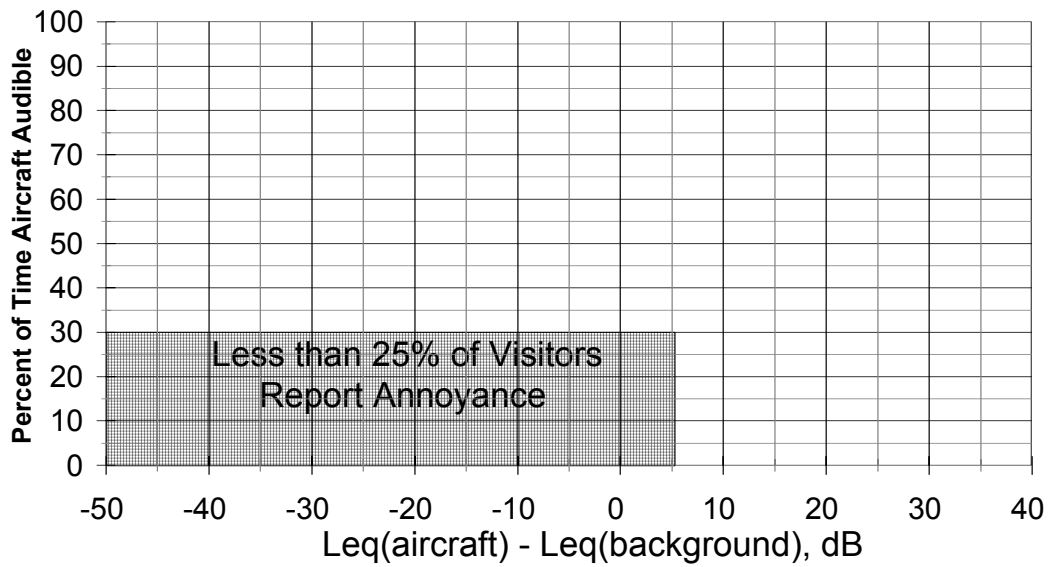


Figure 9. Graphic Representation of Thresholds that Limit Annoyance to 25% of Visitors

Site Categorization by Intrusions

All Aircraft Overflights

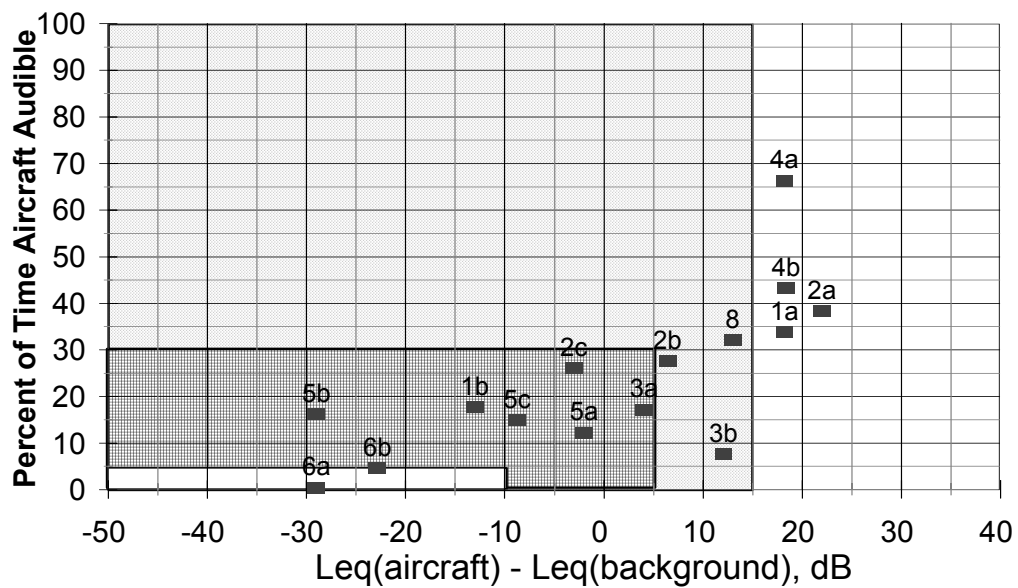


Figure 10. Measurements Made at Sites in Rocky Mountain National Park

6. SUMMARY OBSERVATIONS

Studies of visitor reactions to aircraft overflights at specific sites in U.S. National Parks have yielded both quantitative and qualitative information that can be useful as an aid to park management decisions. The information shows how visitors' sensitivity to tour aircraft noise can vary considerably from site to site, and depends upon whether visitor annoyance is the primary issue, or whether visitor perception of interference with natural quiet is the main concern. Quantitative relationships between sound intrusions and visitor reactions should be useful in general assessments of the effects on visitors of different amounts of aircraft noise at specific park sites. Such assessments, however, must consider that visitor sensitivities are variable site-to-site, as are all aspects of the sound environment. In the end, the type of information provided in this paper provides only one perspective on an issue that has many dimensions, but the quantitative information presented gives a starting point for discussion and problem solving, not the complete answer.

¹ For a complete description of the Dose-Response study and method, see “Dose-Response Relationships Derived from Data Collected at Grand Canyon, Haleakala and Hawaii Volcanoes National Parks,” Anderson, G.S., *et al*, October 1993, HMMH Report No. 290940.34, NPOA Report No. 93-6.

² See “Report on Effects of Aircraft Overflights on the National Park System,” Report to Congress, U.S. Department of the Interior / National Park Service, July 1995. Exit surveys conducted at 39 parks showed similar trends of more visitors always reporting interference with natural quiet than reporting annoyance. Table 6.5 of this Report to Congress gives the specific, park-by-park quantitative results.

³ See Appendix F of Anderson, G.S., *et al*.

⁴ See “Mitigating the Effects of Military Aircraft Overflights on Recreational Users of Parks,” Miller, N.P., *et al*, HMMH Report No. 294470.04. (This report is in draft form as of Jan. 1999).

⁵ The determination of how much annoyance or interference is too much is naturally a policy decision. For the purposes of describing the general method proposed here, we choose to use 25% of visitors annoyed or interfered with as limits of acceptability.